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# Gordon Research Conference Solid State Studies in Ceramics

## FINAL PROGRESS REPORT

DAAHC4-94-G-0234

The Gordon Conference on "Architectural Design of Ceramic Structures for Optimum Performance" was held August 14th to 19th, 1994 at New Hampton School, New Hampton, NH. The conference had ninety-nine participants, with representatives from 10 different countries (attendee list attached). There was a healthy mixture of scientists from universities, national laboratories, military research establishments and private industry. In addition, the poster session allowed a large number of post-doctoral fellows and graduate students to attend the conference (30). Of these 30 young scientists, financial support was available for 24 from the funding agencies that supported the conference (ONR, ARO, NSF, Sandia and the Gordon Research Conference Special Fund). There was a total of 39 posters presented (program attached) and although this was substantially more than previous years, there was general agreement that this approach was very successful. If one includes the rest of the speakers and the discussion leaders with the poster presenters, one finds that two-thirds of the conference attendees were formally involved in the conference.

The program for the oral presentations brought together scientists from several different areas, e.g., statistical mechanics, geology, industrial processing, physics, engineering mechanics, computer simulation, who shared an interest in the conference theme. An important aspect of the program was to ask the speakers to integrate their ideas into the conference theme and the response to this idea was excellent. The topics of the oral presentations were 1) Theoretical Aspects of Structure/Property Relationships, 2) Processing of Novel Ceramic Structures, 3) Nanoscale Effects, 4) Challenges in Property Evaluation, 5) Microstructural Effects on Mechanical Behavior, 6) Design of Fiber Composites and 7) Macrostructural Effects on Mechanical Behavior (see attached program). The number of speakers was limited to two per session and this has been found to be a very successful format, as it allows for 45 minute discussion periods at the end of each talk. The discussion periods were vigorous throughout the conference and many attendees indicated they often learnt as much from the discussion as the talks. There was a total of 16 speakers and 9 discussion leaders. The Thursday evening talk was somewhat more informal and Professor Kroto gave a very entertaining talk on the discovery of Buckminsterfullerene yet it was full of insight into the research process.

In the talks, the speakers from the theoretical mechanics showed how the progress in effective medium theories and statistical theories of fiber failure could be applied to ceramic

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materials. These were areas that were not fully appreciated by the ceramics community. Speakers from industry showed how computer simulation and processing developments could be used to lead to property improvement, while another speaker gave example of how processing could lead to structure control at all scale levels. Another important challenge to ceramic scientists is the measurement of properties at fine scales and two of the talks showed the latest development in these areas. It was also clear after one of the talks that there is a strong need to develop a better understanding of electrically-induced failure in ceramic materials. The other talks discussed the latest developments in controlling properties by manipulating structure from nanoscale levels (e.g., grain boundary phases) to the macroscopic level (laminates). Overall, from the comments of the conferees, it was clear that the conference was very successful and will, I believe have a strong impact on new developments in the field.

## FINAL PROGRAM

### SUNDAY EVENING

6:00 pm      Reception

### MONDAY MORNING: Theoretical Aspects of Structure/Property Relationships

Discussion Leader:    \* Craig Carter, NIST.

- \* S. Torquato, Princeton University, Microstructure-Property Relations for Composite Materials
- \* M. Anderson, Exxon Research, Computer Simulations of Structure/Property Relationships

### MONDAY EVENING. Processing of Novel Ceramic Structures

Discussion Leader:    \* M. P. Harmer, Lehigh University

- \* I. A. Aksay, Princeton Univ., Processing Techniques for Design of Novel Microstructures
- \* A. Pyzik, Dow Chemical, Processing and Properties of Self-Reinforced Silicon Nitride

### TUESDAY MORNING. Nanoscale Effects

Discussion Leader:    \* D. A. Bonnell, University of Pennsylvania

- \* R. Raj, Cornell U., Design of Grain Boundary Phases for Optimum Mechanical Performance
- \* W. Pompe, Max Planck Society, The Role of Microscopic Residual Stresses in the Design of Ceramic Structures

### TUESDAY EVENING. Challenges in Property Evaluation

Discussion Leader:    \* H. M. Chan, Lehigh University

- \* G. M. Pharr, Rice U., Evaluation of Mechanical Properties at the Micro- and Nanoscale
- POSTER SESSION

### WEDNESDAY MORNING. Microstructural Effects on Mechanical Behavior

Discussion Leader:    \* B. R. Lawn, NIST

- \* M. V. Swain, CSIRO, Australia, Mechanical Behavior of Thin Films
- \* Z. Suo, UCSB, Fracture and Breakdown in Dielectric Ceramics

### WEDNESDAY EVENING. Design of Fiber Composites

Discussion Leader:    \* W. Curtin, VPI.

- \* S. L. Phoenix, Cornell Univ, Stochastic Effects in the Failure of Fiber Composites
- \* B. Cox, Rockwell Intl., Optimization of Fiber Architecture in Fiber Composites

### THURSDAY MORNING. Microstructural Effects on Mechanical Behavior

Discussion Leader:    \* D. B. Marshall, Rockwell International

- \* J. Lamon, Domaine Universitaire, Interface Design in Composite Materials
- \* D. K. Shetty, Univ of Utah, Role of Dispersed  $\text{Al}_2\text{O}_3$  on Strength and Toughness in Ce- and Y-TZP

### THURSDAY EVENING. Guest Speaker

Discussion Leader:    \* D.J. Green, Penn State

- \* H. Kroto, University of Sussex,  $\text{C}_{60}$ : Buckminsterfullerene, the Celestial Star that Fell to Earth.

### FRIDAY MORNING. Macrostructural Effects on Mechanical Behavior

Discussion Leader:    \* D. S. Wilkinson, McMaster University

- \* R. F. Cook, IBM Corporation, Effects of Macroscopic Residual Stresses on Fracture
- \* T-F Wong, SUNY Stony Brook, Fracture Mechanisms in Geological Structures

## POSTER SESSION

### THEORETICAL ASPECTS

1. SIMULATION OF STRESS-STRAIN BEHAVIOR OF FIBRE-TOUGHENED CERAMIC COMPOSITES,  
Konstanza Lambrinou, E. Vanswijgenhoven, M. Wevers and O. Van Der Biest.
2. FRACTURE OF HETEROGENEOUS MATERIALS WITH CONTINUOUS DISTRIBUTIONS OF LOCAL BREAKING STRENGTHS,  
Paul Leath, Rutgers Univ. and Phil Duxbury, Michigan State.
3. EVOLUTION OF MICROCRACKING IN LAYERED CERAMIC COMPOSITES  
Sandeep Muju\* and Peter Anderson, Ohio State University
4. MICROSTRUCTURE DESIGN OF HETEROGENEOUS BRITTLE MEDIA,  
Fred Haubensack\* and Ali Argon, Massachusetts Institute of Technology.
5. MODELLING TRANSFORMATION STRESSES & CRYSTALLIZATION KINETICS OF THE AMORPHOUS PHASE IN  $Si_3N_4$   
Hannes Kessler\* Arthur H. Heuer, Case Western Reserve University, Cleveland, Ohio, Mathias Herrmann, Fraunhofer-Institute for Ceramic Technologies and Sintered Materials and Wolfgang Pompe, Max-Planck-Research-Group, Dresden, Germany.
6. SPACE CHARGE DIFFUSIONAL CREEP IN IONIC CERAMICS  
J. Jamnik\* and R. Raj, Cornell University

### PROCESSING OF NOVEL STRUCTURES

1. RHEOLOGICAL BEHAVIOR OF POLYMER-STABILIZED CERAMIC SUSPENSIONS: ROLE OF "FREE" POLYMERIC SPECIES  
Jennifer Lewis, A.L. Ogden, and R. Slilaty, University of Illinois, Urbana
2. BIOLOGICALLY MOTIVATED PROCESSING OF AN ALL-CERAMIC CROWN,  
William Wolf\*, Kaushik Vaidya and Lorraine Francis, University of Minnesota.
3. SYNTHESIS OF NANOCRYSTALLINE  $TiO_2$  THIN FILM ONTO SELF-ASSEMBLED ORGANIC MONOLAYER  
Hyunjung Shin\*, R. Collins, M. R. De Guire, C. N. Sukenik and A. H. Heuer, Case Western Reserve University.
4. TEXTURED ALUMINA,  
Thierry Carisey and David Brandon, Technion- Israel Institute of Technology.
5. MICROSTRUCTURAL CONTROL THROUGH GRAIN BOUNDARY PINNING  
Laura Stearns\* and Martin P. Harmer, Lehigh University
6. NANO-SIZED CORUNDUM & A NEW NANO-SIZED ALUMINA FROM LOW TEMPERATURE CONVERSION OF DIASPORE.  
Tony Perrotta, Charles Misra, Dean Tzeng, Mark Weaver, Neil Dando and Alan Pearson, Alcoa Technical Center  
and Altaf Carim, Penn State.

### INTERFACES

1. FRACTURE TOUGHNESS OF  $Ni/Al_2O_3$  INTERFACES  
Alan Zehnder and Mark Thurston, Cornell University

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\* Conference Scholarship

2. THE EFFECT OF FLAWS ON THE PROPAGATION OF CRACKS AT BI-MATERIAL INTERFACES  
Ivar Reimanis, A. Mammoli, A. Graham and D. Tullock, Los Alamos National Laboratory.
3. AFM MEASUREMENTS OF METAL-CERAMIC INTERFACE PLASTICITY,  
Jim Kiely\* and Dawn Bonnell, University of Pennsylvania.
4. STRENGTH-STRUCTURE-CHEMISTRY RELATIONSHIPS FOR METAL-CERAMIC INTERFACES.  
Vijay Gupta, Jun Yuan and Alexander Pronin\*, Dartmouth College.
5. STRUCTURAL AND MECHANICAL PROPERTIES OF SAPPHIRE-ALUMINA INTERFACES,  
Tony Cazzato\* and Kathy Faber, Northwestern University.
6. SOLID SOLUBILITY AND INTERDIFFUSION IN ZIRCONIA/ALUMINA INTERFACES,  
Matt Stough\* and John Hellmann, Penn State.
7. THERMAL DEPENDENCIES OF STUDIES ON CHEMICAL VARIATION IN YAG SINGLE CRYSTALS AND FIBERS  
Kelly Brown\* and Dawn Bonnell, The University of Pennsylvania.
8. COMPUTATIONAL AND EXPERIMENTAL STUDY OF CRACK PROPAGATION NEAR METAL/CERAMIC INTERFACES,  
Jim McNaney, R. M. Cannon and R. O. Ritchie, LBL, UC Berkeley..
9. THE ROLE OF INTERFACIAL MICROMECHANICS ON THE MICRO- AND MACRO- MECHANICAL RESPONSE OF FIBER REINFORCED COMPOSITES  
Liz Butler\*, Rutgers University and Ed Fuller, Jr., NIST

#### MICROSTRUCTURAL EFFECTS ON FRACTURE AND DEFORMATION

1. EFFECTS OF MICROSTRUCTURE ON SUBSURFACE DAMAGE & MECHANISMS OF MATERIAL REMOVAL IN SCRATCHING, Hockin Xu, NIST.
2. MICROSTRUCTURAL CONTROL AND MECHANICAL PROPERTIES OF MULLITE-ZRO<sub>2</sub>-AL<sub>2</sub>O<sub>3</sub> CERAMICS,  
Takashi Mitamura and H. Kobayashi, Saitama University,  
Y. Kubota and H. Yamamura, TOSOH Co.
3. IN-SITU TOUGHENED SILICON CARBIDE  
Nitin Padture and Brian Lawn, NIST.
4. MICROSTRUCTURE AND ITS RELATIONSHIP TO STRENGTH VARIABILITY IN ALUMINA CERAMICS,  
Desi Kovar\*, Carnegie Mellon University, Mike Readey, Sandia National Laboratories and Brian Lawn, NIST.
5. EFFECT OF GRAIN MORPHOLOGY ON THE MECHANICAL BEHAVIOR OF IN-SITU TOUGHENED CERAMIC COMPOSITES,  
L. An\* and Helen Chan, Lehigh University.
6. FLAW TOLERANT BEHAVIOR OF ALUMINA MULLITE CERAMICS WITH BIMODAL GRAIN SIZE DISTRIBUTION  
A. Khan\*, Martin Harmer and Helen Chan, Lehigh University.
7. EFFECT OF THE GRAIN BOUNDARY PHASE ON THE FRACTURE TOUGHNESS OF SILICON NITRIDE  
Irene Petersen\* and T. Y. Tien, University of Michigan
8. INFLUENCE OF ANNEALING ON RESIDUAL STRESS INTENSITY OF INDENTATION CRACKS IN Si<sub>3</sub>N<sub>4</sub>,  
R. Kurth and Rolf Steinbrech, Forschungszentrum Julich GmbH, Germany.

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\* Conference scholarship

9. MECHANICAL PROPERTIES OF POROUS CERAMICS

Jurgen Rodel, T. Ostrowski, TH Damstadt, M. Knechtel, TU Hamburg-Harburg and R. Bordia, University of Washington.

10. STRENGTH AND RELIABILITY OF METAL/CERAMIC COMPOSITES WITH INTERPENETRATING NETWORKS

Mathias Knechtel\*, H. Prielipp, Nils Claussen and Jurgen Rodel, TU Hamburg-Harburg.

11. WAKE ZONE MODIFICATIONS OF LINEAR ELASTIC COMPLIANCE CURVES

Jack Hay\* and Ken White, University of Houston

12. R-CURVE BEHAVIOR AND SUB-CRITICAL CRACK GROWTH AT ELEVATED TEMPERATURES,

Jim Webb\*, Karl Jakus and John E. Ritter, University of Massachusetts.

13. TENSILE CREEP BEHAVIOR OF  $Al_2O_3$ -SiC NANOCOMPOSITES

Mark Thompson, Helen Chan and Martin Harmer, Lehigh University

14. THE EFFECT OF PLATELET ORIENTATION ON THE CREEP BEHAVIOUR OF SiC REINFORCED ALUMINA

Rosaura Ham-Su\* and David Wilkinson, McMaster University.

15. TIME-DEPENDENT STRENGTH OF POLYCRYSTALLINE SILICON CARBIDE FIBERS AT HIGH TEMPERATURE

Kevin Rugg\* and Richard E. Tressler, Penn State.

16. EFFECTS OF TEXTURES AND PLASTIC ANISOTROPY IN IONIC CERAMICS

Keith Kruger\* and Keith Bowman, Purdue University.

MACROSCOPIC EFFECTS IN FRACTURE

1. EFFECTS OF CRACK VELOCITY ON FRACTURE FEATURES OF ALUMINA

Kaiyang Zeng and David J. Rowcliffe, Royal Institute of Technology, Sweden

2. PROCESSING AND MECHANICAL PROPERTIES OF HIGH TEMPERATURE HYBRID MULTILAYER COMPOSITES,

Willard Cutler\*, Frank Zok and Fred Lange, University of California Santa Barbara

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\* Conference scholarship

**Gordon Research Conference  
Solid State Studies in Ceramics  
New Hampton School  
August 15-19, 1994**

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